The Jinshajiang suture zone: tectono-stratigraphic subdivision and revision of age

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Abstract Integrated study of rock assemblage, tectonic setting, geochemical feature, fossil contained and isotopic geochronology on the metamorphic mixed bodies, exposed in the Jinshajiang suture zone, suggests that one informal lithostratigraphic unit, the Eaqing Complex, and three tectono-stratigraphic units, the Jinshajiang ophiolitic melange, the Gajinxueshan Group and the Zhongxinrong Group, can be recognized there. It is first pointed out that the redefined Eaqing Complex might represent the Meso- to Neo-Proterozoic remnant metamorphic basement or microcontinental fragment in the Jinshajiang area. The original rocks of it should be older than (1627±192) Ma based on the geochronological study. The zircon U-Pb age of plagiogranites within the Jinshajiang ophiolitic assemblage is dated for the first time at (294±3) Ma and (340±3) Ma respectively. The Jinshajiang ophiolite is approximately equivalent to the Ailaoshan ophiolite in the formation age, covering the interval from the Late Devonian to the Carboniferous. Dating of U-Pb age from basalt interbeds indicates that the redefined Gajinxueshan Group and Zhongxinrong Group may be considered Carboniferous to Permian and latest Permian to Middle Triassic in age. In geotectonic terms the Jinshajiang suture zone is thought to be a back-arc basin in the eastern margin of the Paleo-Tethys. This back-arc basin started in the Late Devonian, and formed in the Devonian-Carboniferous. The collision event around the Permian/Triassic boundary to the Middle Triassic led to the closure of the back-arc basin and formation of suture.

Keywords: Jinshajiang suture zone, complex, ophiolitic melange, Paleo-Tethys.

The Jinshajiang suture zone, starting at Weixi, western Yunnan, extends north along the Jinshajiang valley via Deqing, Yunnan and Derong, western Sichuan. So far there is no evidence to prove whether this suture zone stretching south is contiguous to the Ailaoshan suture zone[1,2]. This suture is situated between the Changdu-Simao block in the west and the Yangzi block (South China Plate) in the east (fig. 1). The original tectonic environment of the Jinshajiang suture zone, which belongs to a wide ocean between the north and south continents[3], or back-arc basin[4,5] or even remnant sea[6], small oceanic basin[7] or multi-island ocean[8], and its ages of origin, spreading and subduction have long been controversial in the study of East Paleo-Tethys origin and evolu-

tion[1,3,7,9] due to limitations of natural and climate conditions, moreover, there has been no establishment of tectono-stratigraphic outline and evidenced reliable age.

1 Tectono-stratigraphic subdivision

The metamorphic rocks widely exposed along both banks of the Jinshajiang were named in proper order from south to north as the Gajinxueshan and Zhongxinrong Groups by the Sichuan Team of Regional Geology (STRG)[1)] in 1977. The former is mainly distributed in the Gajinxueshan area, to the west of Derong, Sichuan and extends southwards to Susong and Xiaruo area of Yunnan. The age of this group was thought to be Permian on the basis of fossils found in the allochthonous rock blocks. The Zhongxinrong Group, named after Zhongxinrong Village, Batang of Sichuan, is usually referred to as Early-Middle Triassic in age. In 1980, STRG[2)] established the Eaqing Group with the Eaqing-Jiaxilaka section and Mangbu-Xiacuoruo section in Batang as representive sections and subdivided it into four lithological members. In the light of the coral and fusulinid fossils found in the allochthonous rock blocks of the ophiolitic melange, Li[6] referred to the Gajinxueshan Group and Zhonxinrong as Permian and Early-Middle Triassic in age respectively. The Chengdu Institute of Geology and Mineral Resources (CIGMR) and Sichuan Bureau of Geology and Mineral Resources (SBGMR)[10], however, replace the Gajinxueshan Group and Zhongxinrong Group with the name Eaqing Group, and subdivided the Eaqing Group into the Lower Permian Laloubu Formation in upper and the Kedabeng Formation in lower. These two formations were established in Changdu region[3)]. The Yunnan Bureau of Geology and Mineral Resources[11] put the Eaqing Group into the Gajinxueshan Group and considered it to be Permian in age. SBGMR[12] basically maintained the subdivision proposed by CIGMR and SBGMR[10], but revised the Erqing Group as a formation with four members and meanwhile put a part of the Zhongxinrong Group into the Permian to Early Triassic ophiolitic melange definition. It is worthy to mention that a number of papers discussing the tectonic evolution of Paleo-Tethys considered the Jinshajiang suture zone[2,4,7,13]. Unfortunately, nearly all these discussions relied on the above-mentioned stratigraphic subdivisions and defined age, or made some revisions to these stratigraphic subdivisions and ages on the basis of different ideas of fossils found in them. As for the tectono-stratigraphy, Hsu et al. (1995)[5] have made an innovation in the tectonic-facies concept in the orogenic belt and suggested that the Jinshajiang suture is of the celtides tectonic-facies belt they defined. Feng[15] discussed the tectono-stratigraphic subdivision in the orogenic belt. This research, however, did not involve any concrete problems of tectono-stratigraphic subdivision within the Jinshajiang suture zone. In fact, the so-called Gajinxueshan Group, Zhongxinrong Group or a part of Eaqing Formation is composed of huge mixed rock bodies or melanges formed in different tectonic settings which underwent poly-phase metamorphism

1) Sichuan Team of Regional Geology, Report of 1/20 thousand geological mapping in Derong area, 1977.

2) Sichuan Team of Regional Geology, Report of 1/20 thousand geological mapping in Ganzi area, 1980.

3) Sichuan Third Team of Regional Geology, Report of 1/100 thousand geological map in Chuangdu area, 1974.

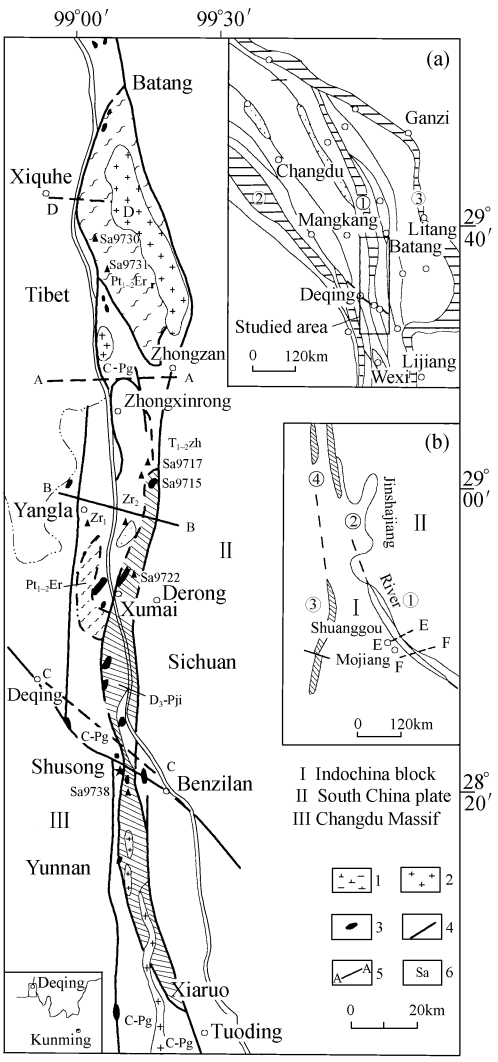


Fig. 1. Geological sketch map of the Jinshajiang suture zone (modified from CIGMR & SBGMR, 1992). 1, Quartz diorite; 2, Indosinian granites; 3, meta-ultramafic rocks; 4, fault; 5, studied sections: A-A, Changbo-Zhongzan; B-B, Ganzhangniuchang-Benjinlong; C-C, Deqing-Benzilan; D-D, Xiquhe; E-E, Yakou-Laowangzhai; F-F, Mojiang-Yuanjiang; 6, sample number for isotope dating: Pt_{1-2} Er, Eaqing complex (Early-Middle Proterozoic); D_3-Pji, Jinshajiang ophiolitic melange (Late Devonian-Permian); C-Pg, Gajinxueshan Group (Carboniferous-Permian); T_{1-2}zh, Zhongxinrong Group (Early-Middle Triassic). (a) Jinshajiang and adjacent area. ① Jinshajiang suture zone, ② Lancangjiang suture zone, ③ Ganzi-Litang suture zone; (b) Ailaoshan suture zone. ① Ailaoshan suture zone, ② Jinshajiang suture zone, ③ Changning-Menglian suture zone, ④ Lancangjiang suture zone.

and deformation along with the evolution of the Jinshajiang ocean basin. Hence stratigraphic succession and age established on the basis of formal stratigraphic principles, which are used to deal with deposits exposed in the stable craton or continental margin, cannot objectively reflect the time and space relationship of these mixed bodies or melanges. Based on the integrated studies of rock assemblage, tectonic setting, fossils contained and isotopic geochronology, it is suggested that four lithostratigraphic units considered, the Eaqing Complex, the Jinshajiang ophiolitic melange, the Gajinxueshan Group and the Zhongxinrong Group, can be recognized in the Jinshajiang suture zone (fig. 2). The former is an informal lithostratigraphic unit, and the latter three are tectono-stratigraphic units. The time and space relationship between them is shown in table 1.

2 Discovery of the Early-Middle Proterozoic basement

The redefined Eaqing Complex, being approximately limited to Member 2 of the original Eaqing Formation[12] and mainly exposed on both banks of the Jinshajiang River, west of Xumai, is composed of high-grade metamorphic rocks, schist, gneiss, plagioclase-amphibolite, and marble with strong migmatization. The metamorphic grade attains high greenschist facies to amphibolite facies. Based on the Ru-Sr age dating of kyanite-bearing two-mica schist (Sa9730) from the Suwalong area between Batang and Zhongza, and U-Pb age dating of plagioclase-amphibolite (Sa9731) from Gadi Village nearby, the Ru-Sr isochron age of former is (423±40) Ma, and the latter gives an upper intercept age of (1627±192) Ma (figs. 3 and 4).

These suggest that the original rocks of these high-grade metamophic rocks should be older than (1627±172)Ma, and that the Ru-Sr isochron age of (423±40) Ma might represent the age of Caledonian metamophic event. The original rock should be older than Devonian in age. These new data first demonstrate the existence of the Early-Middle Proterozoic remnant metamorphic basement or microcontinental fragment in the Jinshajiang area, which are equivalent to the Ailaoshan Complex in tectonic setting and horizon.

3 New knowledge on the age of Jinshajiang ophiolitic melange

The Jinshajiang ophiolitic melange stretches along the Jiashajiang suture zone, and is well exposed in the Baimongxiushan, Shusong and Gongka, Xiaruo-Tuoding, and Xumai-Xuedui areas (figs. 1 and 2). Zhang et al.[16] and Mo et al.[2,3] have done some researches and considered that they possess characteristics of typical ophiolitic assemblage, but its succession was disrupted in varying degrees. The Reginal Geological Survey of SBGMR (1977) did not separate the ophiolitic melange from the Gajinxueshan Group and Zhongxinrong Group when establishing these two stratigraphic units, because of the similarity between them in structure and metamorphic characteristics. In 1979, Zhang and Jin[17] studied the tectonic setting of the Jinshajiang suture zone and first proposed the name of the Jinshajiang ophiolitic melange belt. Afterwards, SBGMR[12,18] first called it the Jinshajiang ophiolitic suite, and then modified it to the Jinshajiang ophiolitic melange litho-group, and referred the larger part of it to the Permian and inferred a part of it to the Triassic in age. The Jinshajiang ophiolitic melange is considered as a special component of the Jinshajiang melange. It differs from the redefined Gajinxueshan Group and Zhongxinrong Group, usually distributed to either side of it, in different rock assemblages. In

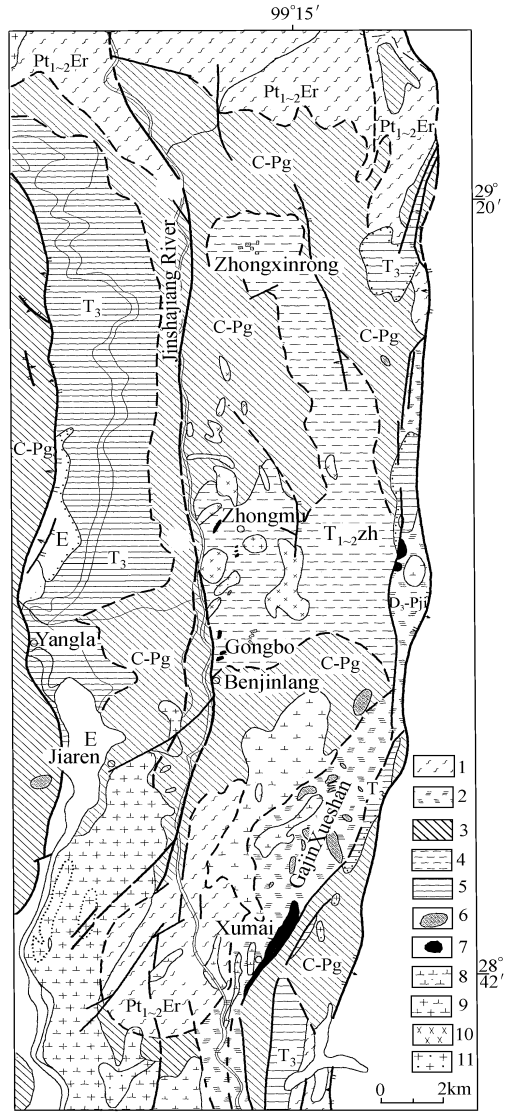
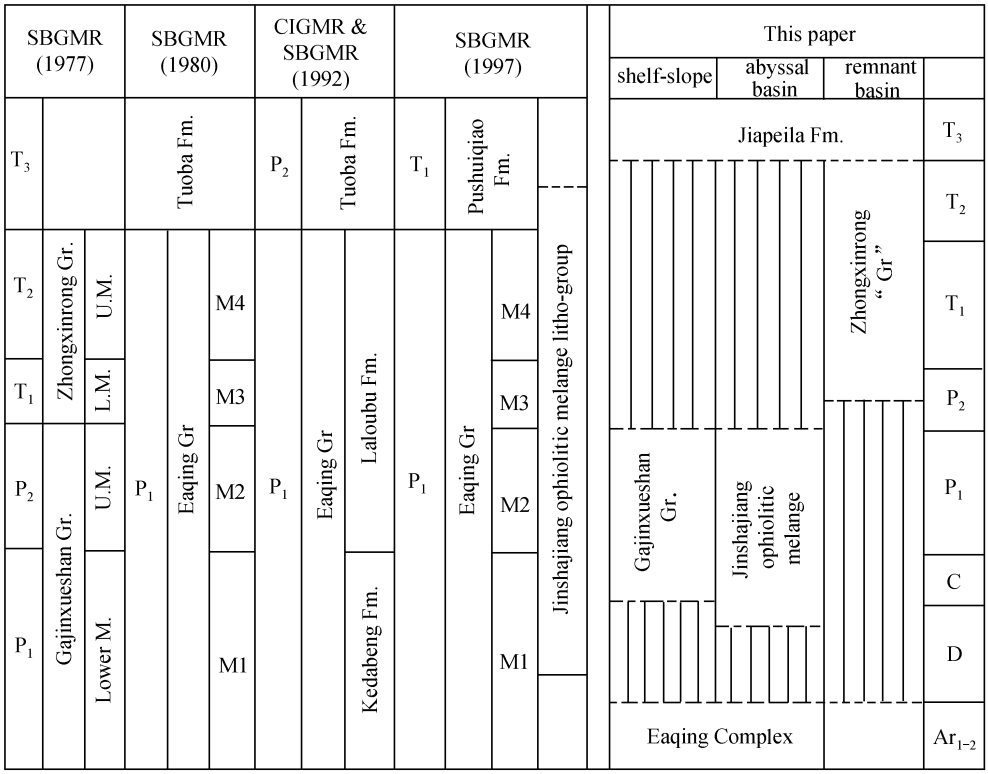


Fig. 2. Distribution of tectono-stratigrapic units in the Jinshajiang suture zone. 1, Eaqing complex; 2, Jinshajiang ophiolitic melange; 3, Gajinxueshan Group; 4, Zhongxinrong Group; 5, Jiapeila Formation; 6, allochthonous rock block; 7, meta-ultramafic rocks, ophiolite; 8, quartz-diorite; 9, granite and quartz-diorite; 10, diabase-gabbro; 11, granodiorite.

Table 1 Tectono-stratigraphic subdivision and correlation of the Jinshajiang-Ailaoshan suture zone



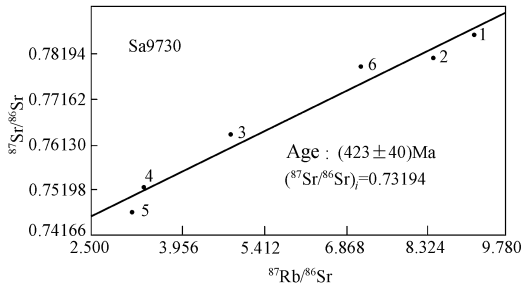


Fig. 3. Ru-Sr isochron of kyanite-bearing two-mica schist from Suwalong area. 1—6, Sample number (Sa 9730-1 to Sa 9730-6).

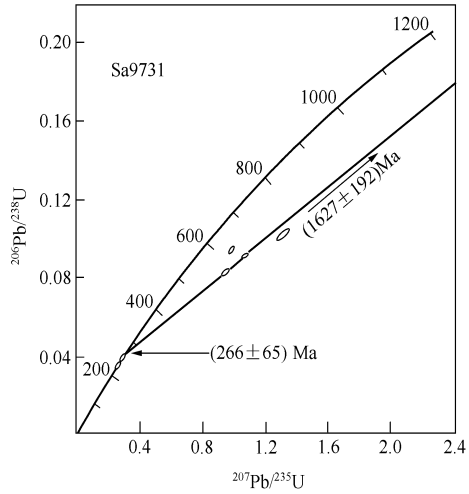


Fig. 4. U-Pb concordia diagram of zircons from the Gadi plagioclase amphibolite.

Baimongxueshan the ophiolitic melange is complex in component and mainly comprises meta-peridotite, cumulus crystal ultramafic rock, gabbro, pillow basalt, diabase, radiolarian-bearing chert and allochthonous limestone and quartz-porphyry, the matrix is deformed clastic rock and

greenschist. The ophiolitic melange in Gonka occurs as an appearance of fault slice and is mainly composed of pillow lava and meta-peridotite intercalated with purple-redish siliceous rock and allochthonous limestone. The ophiolitic melange in Susong area is characterized by meta-peridotite, cumulus crystal pyroxenolite, plagiogranite and black radiolarian-bearing siliceous rock. In Tuoding and Xiaruo area the ophiolitic melange is predominated by cumulus crystal rock, along with pillow lava and radiolarian-bearing chert. The ophiolitic melange of Xuedui is similar to that of Susong but having a larger scope. The study of zircon U-Pb age, which was made by one of the present authors (Jian Ping) for the plagiogranites within the ophiolitic assemblages separately exposed in the roadside of Susong, western Yunnan and Xuedui, western Sichuan, suggests for the first time that their zircon U-Pb ages are (340±3) Ma and (294±3) Ma, respectively[1)]. These two plagiogranites separately occur within the meta-peridotite by form of block or vein. Their chemical components are analogous to that of oceanic plagiogranite defined by Coleman[19]. The appearance of these two plagiogranites are related to the differentiation of ophiolitic magma and represent the final product of calcic-alkalic basalt differentiation. These two plagiogranite U-Pb ages, therefore, may indicate the formation age of the Jinshajiang ophiolitic rocks. The ophiolitic melange of the Ailaoshan suture zone is quite similar to that of the Jinshajiang ophiolitic melange in rock assemblages and metamorphic and deformation characteristics, and well exposed in the Shuanggou to Mojiang area. Based on the zircon U-Pb age dating from the Shuanggou plagiogranite and Longtang gabbro within the Ailaoshan ophiolitic assemblage given by one of the present authors [20], the age of the former is (328±16) Ma and the lower intercept age of the latter (362±41) Ma. These ages are basically identical to that obtained from the Jinshajiang plagiogranites. Thus we imagine that the Jinshajiang and Ailaoshan ophiolitic rocks are equivalent to each other in age, forming in the Late Devonian to the Late Carboniferous. Besides, some Devonian-Permian radiolarians and conodonts were found in the abyssal cherts from the Jinshajiang and Shuanggou ophiolitic mélanges[3,21—23] (modifying here the Ailaoshan ophiolitic melange as the Shuanggou ophiolitic melange, since the name of Ailaoshan has been used for the Ailaosha Complex). Wang Chuanshan has also found radiolarians in the chert intercalated within the ophiolitic melange from Gonka and Xiarou of Benzilan, Deqing. The main elements of radiolarians, which are revised by Dr. Freneisc of the University of New England, Australia, include *Albaillella* sp., *Pseudoalbaillella sakamarensis* (Kozur)?, *Follicucullus ventricosus* (Ormiston & Bubcock), *F.* sp. belonging to Early Permian age. Some Devonian-Carboniferous conodonts, *Apathognathus*? sp., *Neopriniodus*? sp., *Sipholodalla*? sp. are found in the limestone block within the ophiolitic melange in Rongjiaoxueshan. Based on these data and above-mentioned interrelated basement existing between the Jinshajiang and Ailaoshan suture zones, it is suggested that the Jinshajiang and Ailaoshan Paleo-Tethys oceanic basins should be considered contiguous and belong to the

1) Wang, X.F., Metcalfe, I., Jian, P. et al., Jinshajiang-Ailaoshan suture zone: tectonostratigraphy, age and evolution, Journal of Asian Earth Sciences (Special issue).

same ocean basin. This oceanic basin was formed not later than around the Devonian/Carboniferous boundary and might have held up to Permian through Carboniferous spreading.

The ophiolitic melange, in general, is doubtless the product or record of replacement of tectonic mixture of ophiolite resulting from plate collision or oceanic subduction [2,14]. When the ophiolitic age was not determined previously in the Jinshajiang suture zone some researchers [2,7] had to rely on "intrusion" of the Jinshajiang ophiolite into the Gajinxueshan Group and Zhongxinrong Group, unconformably overlain by the Late Triassic molasse suite, to explain why the replacement of the Jinshajiang ophiolite and the formation of ophiolitic melange should be from the Late Permian to early Late Triassic in age. In fact, not all ophiolites exposed in the suture zone can be considered as evidence for the intercontinental collision. Some of them present in the suture may have been formed by arc-arc collision, caused by the subduction of the oceanic crust of back-arc basin under the island arc, as Hsu et al. have suggested [5]. The Jinshajiang-Ailaoshan suture zone is a back-arc basin of the main oceanic basin of Paleo-Tethys, represented by the Lancangjiang and Changning-Menglian suture in SW China to the Bentong-Raub suture in Peninsular Malaysia. It was formed along the western margin of the South China block during the Late Devonian to Permian, following back-arc extension started at the Early Devonian and rifting of the Changdu-Simao block from the margin of the South China block. Previously mentioned new isotopic geochrological data further indicate that the Jinshajiang ophiolite should be a product of intercontinental rifting and oceanic crust spreading. The Jinshajiang ophiolitic melange, and revised Gajinxueshan Group are thought to be the tectonic melange bodies or rock slices of simultaneous, but different facies formed in different tectonic settings of the Jinshajiang back-arc basin in association with spreading of oceanic crust and replacement of ophiolite (table 1). Moreover, to date we know no unequivocal evidence to prove that the intrusion of the Jinshajiang ophiolite into the Gajinxueshan Group, or into the Zhongxinrong Group, resulted from the collision event during around the Permian and Triassic boundary to the Middle Triassic. The Jinshajiang ophiolitic melange should belong to the latest Devonian to Permian age in the light of these data as follows: (i) isotopic age of the Jinshajiang ophiolite, (ii) the incoming of Devonian to Permian radiolarian and conodont fossils[21—23] in the abyssal siliceous rock and allochthonous limestone of the Jinshajiang ophiolitic melange respectively, and (iii) the isotopic geochronological study of volcanic interbeds of the Gajinxueshan Group mentioned below.

4 Tectonic setting of Gajinxueshan and Zhongxinrong groups

Restudy shows that the originally named Gajinxueshan Group, Zhongxinrong Group and the Eaqing Group or Formation are different in the rock assemblage, metamorphic degree and tectonic setting of formation except for the overlapping parts between them. It is not suitable to abolish these names. The Gajinxueshan Group, here redefined as including the major part of the original

Gajinxueshan Group and the lower part of Zhongxinrong Group, is characterized by meta-clastic flysch formation of bathyal slope facies intercalated with the basic volanic rocks and allochthonous limestone blocks and carbonate suites of the shallow-bathyal shelf facies with volcanic interbeds. The representive sections are separately located at the Dongda to Beiwu, Yangla Village on the western bank of the Jinshajiang River and from Ganzhangniuchang to Benjinnong in the eastern bank of the Jinshajiang. Basalt interbed collected from this group on the western bank of the Jinshajiang is dated at the U-Pb ages of (362±9) Ma(Zr_1)—(296±7) Ma (Zr_2) by Zhan et al.[24], showing that this group is of Carboniferous-Permian age.

Here the redefined Zhongxinrong Group, repersented by the Nonggela section, Zhongzai, Batang, only includes a part of the original Zhongxinrong Group. It is characterized by flysch clastic sediments, consisting of low grade metamorphosed flysch suite with interbeds of thin-bedded limestone and rare basic volcanic rock. The isotopic geochronological dating of syn-collision gabbro (SA9715), granite (SA9717) and foliated granite (SA9725), separately intruded into the Zhongxinrong Group of Zhongmu and Xumai areas, which is made by one of the authors (Jian Ping), gives their Rb-Sr ages of (227±5) Ma (SA9715), (255±8)Ma (SA9717) and (238±18)Ma (SA9725), respectively (figs. 5—7). It shows, hence, that the Zhongxinrong Group would be formed in the bathysal to abyssal remnant basin during the collision orogenic state. The collision event probably started in the Permian/Triassic boundary and ranged up to the Middle Triassic.

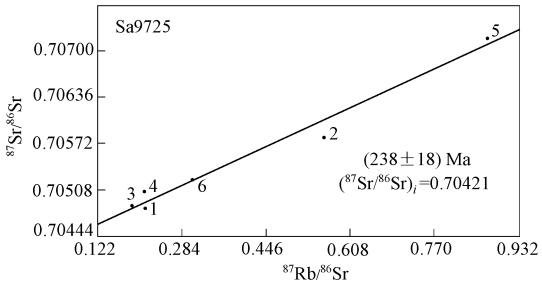


Fig. 5. Rb-Sr isochron of the Xumai foliated granite. 1—6, Sample number (Sa 9725-1 to Sa 9725-6).

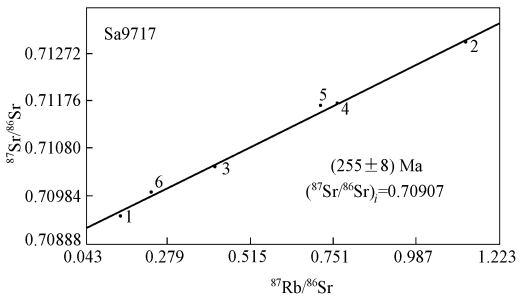


Fig. 6. Rb-Sr isochron of the Zhongmu granite. 1—6, Sample number (Sa 9717-1 to Sa 9717-6).

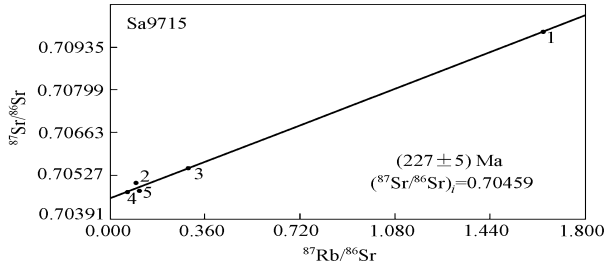


Fig. 7. Rb-Sr isochron of the Zhongmu gabbro. 1—5, Sample number (Sa 9715-1 to Sa 9715-5).

5 Tectonic setting and evolution of the Jinshajiang suture zone

Basalt and diabase are thought to be the best indicators for the genesis and tectonic environment among ophiolitic rock associations[25]. The Jinshajiang ophiolitic melange is dominated by metamorphic ultrabasic rocks and basalt, along with a small amount of diabase. The study of the elemental composition, and trace and rare earth elemental distribution pattern of the basalts collected from the Jinshajiang-Ailaoshan ophiolitic melange zone, which was made by one of the authors (He Longqing), show that (i) SiO_2 content varies between 35.98% and 51.60%, belonging to unsaturated rock, (ii) Al_2O_3 is relatively low ranging from 9.31% to 17.77%, (iii) TiO_2 is relatively high, usually varying from 0.72% to 3.25%, (iv) MgO content is average for most samples but with occasional lower content, (v) K_2O is relatively high, ranging from 0.02% to 1.39%. In contrast to mid-oceanic ridge basalts (MORB), the basalts from the Jinshajiang ophiolitic melange appear to be different in the relatively high content of K_2O. However, the diagram of the FeO^*/MgO-TiO_2 (fig. 8) shows that the distribution of data points from the basalts of the Jinshajiang ophiolitic melange are scattered across the mid-oceanic ridge basalt (MORB), oceanic island basalt (OIB) and island arc tholelite (IAT) field. This elemental composition distribution appears to be similar to that of the basalts from the ophiolitic rocks of the Ailaoshan suture zone. In the FeO^*-MgO-Al_2O_3 plot (fig. 9), the distribution of data points of basalts from the Jinshajiang or Ailaoshan ophiolitic melange zones are mainly confined to the MORB, OIB and continental volcanic rock regions. The ATK diagram (fig. 10) shows that most data points fall on the continental rifting area, but then a few points also occur in the MORB field. All three diagrams indicate that the basalts, exposed in the Jinshajiang ophiolitic melange zone, could probably be derived from different tectonic position situated between the MOR and continental margin. On the other hand, the study of the rare earth element (REE) distribution of the basalt from the Jinshajiang ophiolitic melange indicates that (i) the REE content is higher than that of MORB. The general content varies between 42.2×10^{-6} and 189.7×10^{-6}. (ii) The REE distribution appears gentle type, without Eu anomaly for the most part, but rather a part with Ce negative anomaly and Eu positive anomaly. (iii) LREE enrichment is medium, usually $(La/Sm)_N>1.5$, showing an obvious difference from the MORB with relatively less LREE and LREE depletion. The geochemical data mentioned above indicates that the tectonic setting forming the Jinshajiang ophiolite might be situated between

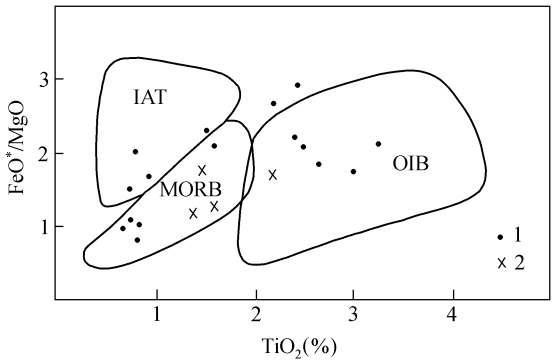


Fig. 8. Diagram showing the FeO^*/MgO-TiO_2 of the Jinshajiang-Ailaoshan basalt. 1, Jinshajiang basalt; 2, Ailaoshan basalt. LAT, Island arc tholelite; MORB, mid-oceanic ridge basalt; OIB, oceanic island basalt.

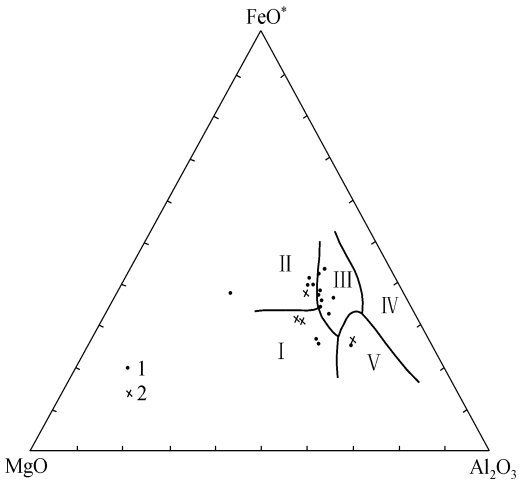


Fig. 9. Diagram of FeO^*-MgO-Al_2O_3 of the Jinshajiang-Ailaoshan suture zone. 1, Jinshajiang basalt; 2, Ailaoshan basalt. I, Mid-oceanic ridge volcanic rock; II, oceanic island volcanic rock; III, continental volcanic rock; IV, volcanic rock of island arc expansion centre; V, orogenic zone volcanic rock.

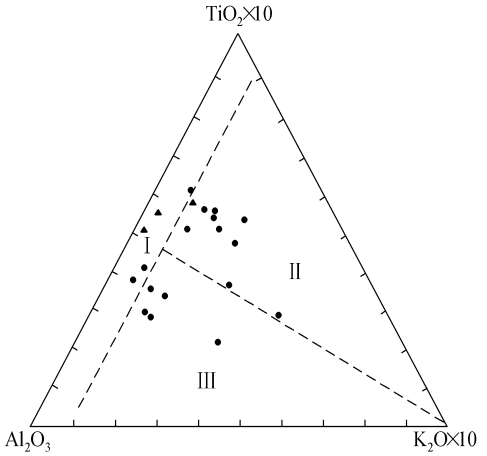


Fig. 10. ATK diagram of the basalt from Jinshajiang suture zone. ●, Jinshajiang zone, ▲, Ailaoshan zone. I, Mid-oceanic ridge basalt; II, continental rift basalt; III, orogenic zone basalt.

MORB and OIB. Considering its regional geotectonic features the present authors are convinced that the Jinshajiang suture zone, palaeogeographically, appears to be of a back-arc basin in the eastern margin of the Paleo-Tethys ocean, formed by back-arc extension. Four evolutionary stages can be recognized for the Jinshajiang suture zone as follows.

5.1 Intracontinental rift stage

In the Changning-Menglian suture zone the Early Devonian fine sandstones and shales intercalated with thick-bedded cherts containing a number of terrigenous materials and graptolites of the *Monograptus uniformis*-Zone along with radiolarians in low diversity, plant fragments, conodonts and ostracodes[26]. The Middle Devonian to Permian deposits there are characterized by the development of abyssal oceanic ribbon-bedded and laminated cherts without terrigenous clastic material, yielding a great deal of radiolarians[8]. It is deduced that the main ocean of Paleo-Tethys represented by the Lancangjiang and Changning-Menglian sutures occurred in the initial sea-flood spreading in the Early Devonian. This was followed by the deposition of Middle-Late Devonian oceanic ribbon-bedded and laminated cherts in the main ocean of the Changning-Menglian along with the extension and subduction of the Palaeo-Tethys oceanic crust beneath South China and Indochina continents in the Early-Middle Devonian. Associated back-arc extension and rifting of the Changdu-Simao massif from the South China Plate or Indosinian Plate led to the creation of the initial Jinshajiang-Ailaoshan back-arc intracontinental basin along the western margin of the South China block. Due to the less than evenly distributed rifting, a few Proterozoic remnant basements or micro-continental fragments were to be retained and formed the Eaqing Complex and the Ailaoshan Complex through polyphase metamorphism as seen today.

5.2 Opening and spreading stage

During the Late Devonian to Carboniferous the Jinshajiang-Ailaoshan back-arc basin came into its oceanic spreading stage from rifting basin, and maintained up to the Permian due to continued extension and subduction of the Lancangjiang-Changning-Menglian ocean. Consequently the Jinshajiang and Ailaoshan ophiolites of the latest Devonian-Early Carboniferous age and the Jinshajiang and Shuanggou ophiolitic melanges, being accompanied by replacement of these ophiolites, occurred along the Jinshajiang-Ailaoshan suture zone. These ophiolitic assemlages include a number of harzburgites, cumulus crystal gabbros, pillow basalts, indicating the oceanic lithospheric spreading. The Early Carboniferous and Permian abyssal facies radiolarian-bearing cherts were present in the middle part of the Jinshajiang-Ailaoshan back-arc basin along with the spreading and formation of oceanic basin. Meanwhile, the flysch and turbidite deposits of abyssal-bathyal slope facies and carbonate deposites of neritic shelf facies intercalated with the volcanic rocks, constituting the Gajinxueshan Group, were developed on both sides of the passive continental margins of the now oceanic back-arc basin. The occurrence of a number of volcanic rocks in this group is likely related to the subduction of the Lancangjiang Paleo-Tethys Ocean toward the Changdu-Simao massif.

5.3 Subduction stage

From about the Early/Late Permian boundary the Jinshajiang-Ailaoshan back-arc basin ceased spreading and began its subduction stage, after which the eastern margin of the Changdu-Simao massif was changed from passive continental margin to active one. It might result in the occurrence of Late Permian to Middle Triassic remnant basin and associated flysch suite of the Zhongxinrong Group, intercalated with the basalt of ca (249±15) Ma. The volcanic (basalt, andesite, liparite) interbeds increase toward the upper part, showing that the Jinshajiang-Ailaoshan back-arc basin could not have closed before the Middle Triassic.

5.4 Collision and close stage

In the Jinshajiang-Ailaoshan suture zone the collision event occurring along with the closure of the oceanic basin led to structural deformation and regional metamorphism of different degrees, with disruption of melange bodies or rock slivers forming in the different tectono-palaeogeographic positions of the Jinshajiang-Ailaoshan back-arc basin during the Early Carboniferous to Permian, or even the Early-Middle Triassic, including the Jinshajiang ophiolitic melange, the Gajinxueshan Group, the Zhongxinrong Group and the equivalent deposits exposed in the Ailaoshan area. The occurrence of the latest Permian-Middle Triassic synorogenic granitoids, such as the Xumai granite of 238 Ma and Zhongmu granites of 255—227 Ma along the orogenic belt indicates that the collision event started in the Permian/Triassic boundary and ranged to the Middle Triassic. The Late Triassic molasse suites (the Jiapila and Yiwanshui Formations), unconformably overlies on the metamorphic rocks of different horizons in the Jinshajiang Ailaoshan suture zone, marking the end of the evolutional history of this suture.

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